

COMPENSATION FOR THE DISTORTION IN SATELLITE LASER RANGE  
PREDICTIONS DUE TO VARYING PULSE TRAVEL TIMES

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ABSTRACT

A method for compensating for the effect of the varying travel time of a transmitted laser pulse to a satellite is described. The "observed minus predicted" range differences then appear to be linear, which makes data screening or use in range gating more effective.

1. INTRODUCTION

Accurate range predictions are necessary in satellite laser range measurements when the operation takes place in daylight. Then the range gate, where the return pulse detector is active, can be set very narrow to effectively discriminate against noise. Data screening of the observations is often done using "observed minus predicted" (O-C) range differences. The predicted satellite times are generally equally spaced, as are the transmit times. But the true hitting times are not equally spaced because of the varying pulse travel times. This leads to distortion of the O-C differences which can be as high as 10-20 m. A polynomial of suitable degree is used in screening. It is well known that the polynomial should be of low degree so as to avoid an artificially good fit or end effects. If the travel time distortion is removed, the O-C deviations are nearly constant with time for high quality orbit predictions. This paper describes and tests a simple correction method.

## 2. METHOD OF RANGE CORRECTION

The range from the laser station to the satellite varies approximately parabolically with time, Fig. 1. When the satellite is passing the closest point, a small time change does not affect the range much. At the far end of the pass the range changes several kilometers per second.

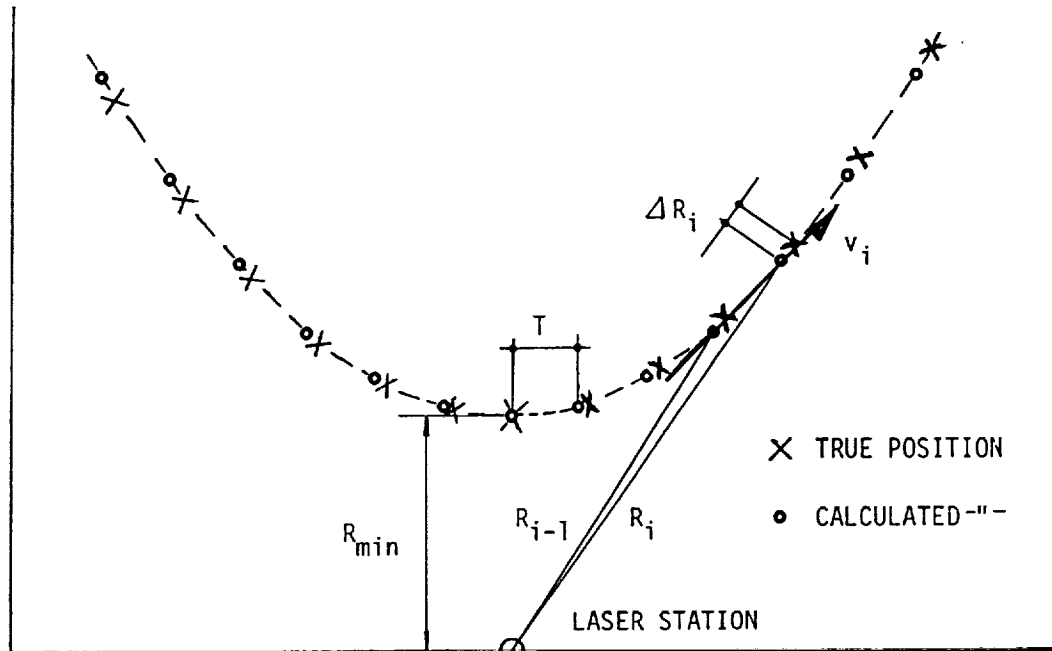


Fig.1 Conceptual scheme for the origin of the travel time distortion in ranges.

This rate,  $v_i$ , can be calculated together with the ranges, or it can be approximated from the change between the successive predicted ranges  $R_{i-1}$  and  $R_i$

$$v_i = (R_i - R_{i-1}) / T, \quad (1)$$

where  $T$  is the time step (often 1 s).

The travel time difference between the minimum range  $R_{min}$ , and the instantaneous range  $R_i$  is

$$\Delta t_i = (R_i - R_{min}) / c, \quad (2)$$

where  $c$  is the speed of light. Then the travel time correction  $\Delta R_i$  to be added to the predicted range is

$$\Delta R_i = v_i * \Delta t_i. \quad (3)$$

### 3. RESULTS AND DISCUSSION

A test with real data is shown in Fig. 2. This LAGEOS pass involved relatively few observations (21). The prediction program used highly accurate long-term IRV predictions /1/. A 220 ms time correction was used in the calculation.

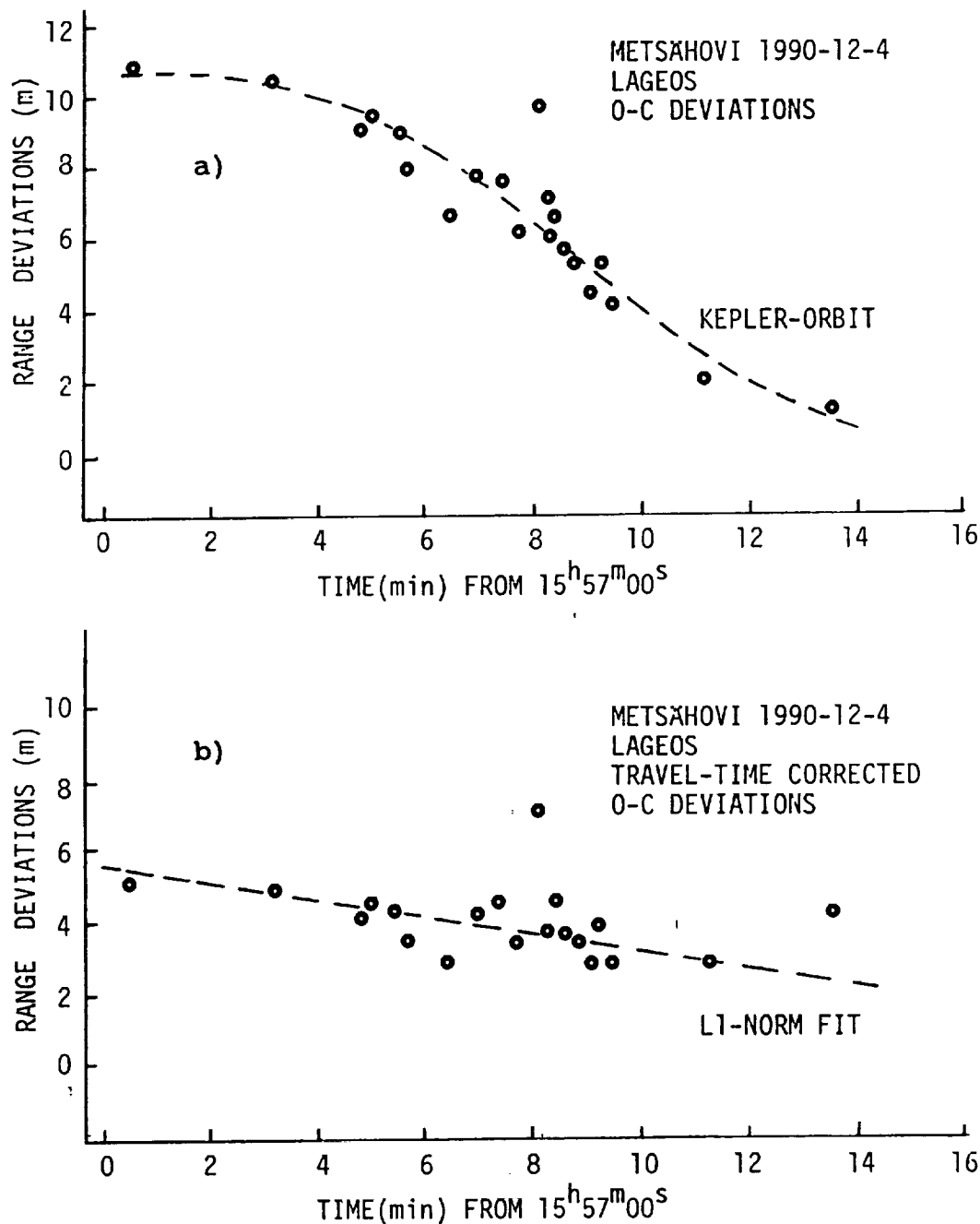


Fig. 2. a) 'Observed-predicted' (O-C) deviations of a measured LAGEOS pass. A Kepler orbit fit is also shown. b) O-C deviations after the travel time correction. A linear median fit is shown.

The time error varies slowly with time, and is normally known from earlier observations. The O-C deviations are shown in Fig. 2a. A simple Kepler orbit /2/ fits the observations quite well, and only one outlier is indicated. In polynomial fitting determination of the order is not easy. The first point would be rejected in a linear fit.

The situation becomes considerably clearer after application of the travel time correction method described (Fig.2b). The fit using the linear L1-norm /3/ eliminated the last point as well as the known outlier. Because the model is now linear, it is not necessary to use higher order polynomials.

This example shows that a very narrow range window is possible in ranging to LAGEOS. A 50 ns window corresponds to 7.5 m of range. This would help considerably in implementing daylight satellite laser range-finding. As has been seen, the method can also help resolve difficult data screening tasks. Good orbit elements and a good orbit are essential for this method.

Note that recalculation of the orbit after the pass, using the satellite hit times, produces approximately the same O-C deviations as the method described.

#### REFERENCES

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